Lossy Transmission Lines

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Introduction:

General:

From Gardiol, Lossy Transmission Lines, p. 168:

$$\alpha + \beta \cdot j = \sqrt{(G' + \omega \cdot C' \cdot j) \cdot (R' + \omega \cdot L' \cdot j)}$$

where: α= attenuation in nepers/U.L. (can be derived from measurements)

β= phase shift in radians/U.L. (can be derived from measurements)

ω= frequency in radians/second (known)

G'= conductance in Siemans/U.L. (unknown)

C'= capacitance in Farads/U.L. (usually given by cable manufacturer or can easily be measured using a short length of line)

R'= resistance in Ohms/U.L. (unknown)

L'= inductance in Henrys/U.L. (unknown)

U.L.= Unit Length

which can be rewritten as: $(\alpha + \beta \cdot j)^2 = (G' + \omega \cdot C' \cdot j) \cdot (R' + \omega \cdot L' \cdot j)$

expanding the expression, yields:

$$\alpha^2 + 2 \cdot \alpha \cdot \beta \cdot j - \beta^2 = R' \cdot G' + \omega \cdot G' \cdot L' \cdot j + \omega \cdot R' \cdot C' \cdot j - \omega^2 \cdot C' \cdot L'$$

collecting real and imaginary terms yields two equations:

$$\alpha^2 - \beta^2 = R' \cdot G' - \omega^2 \cdot C' \cdot L' \quad \text{and} \quad 2 \cdot \alpha \cdot \beta = \omega \cdot G' \cdot L' + \omega \cdot R' \cdot C'$$

solving for α in the second yields: $\alpha = \dfrac{\omega \cdot G' \cdot L'}{2 \cdot \beta} + \dfrac{\omega \cdot R' \cdot C'}{2 \cdot \beta}$

However, we have three unknowns. We need three equations.

High Frequency Case:

The third equation can be obtained by making measurements at two different frequencies to separate the conductor and dielectric losses.

Let $A_1 = m\cdot\sqrt{f_1} + n\cdot f_1$ and $A_2 = m\cdot\sqrt{f_2} + n\cdot f_2$

where: A_1 = measured attenuation in decibels/U.L. at frequencf_1

A_2 = measured attenuation in decibels/U.L. at frequencf_2

$m, n =$ constants U.L.= unit length

solving for m and n yields:

$$m = \frac{A_1\cdot f_2 - A_2\cdot f_1}{f_2\cdot\sqrt{f_1} - f_1\cdot\sqrt{f_2}} \qquad n = \frac{A_2\cdot\sqrt{f_1} - A_1\cdot\sqrt{f_2}}{f_2\cdot\sqrt{f_1} - f_1\cdot\sqrt{f_2}}$$

These equations can now be used to solve for the total attenuation, A, at any frequency, f, as well as the conductor loss, Ac, and the dielectric loss, Ad.

$$A = Ac + Ad \qquad Ac = m\cdot\sqrt{f} \qquad Ad = n\cdot f \qquad \text{in dB/U.L.}$$

And:

$$\alpha = \frac{A}{\left(\frac{20}{\ln(10)}\right)} \qquad \alpha c = \frac{Ac}{\left(\frac{20}{\ln(10)}\right)} \qquad \alpha d = \frac{Ad}{\left(\frac{20}{\ln(10)}\right)} \qquad \text{in Nepers/U.L.}$$

β can be measured or derived from cable maufacturer's data by the following formula:

$$\beta = \frac{\omega}{vp}$$ where: vp = relative phase velocity (dimensionless)

Now we have three equations to find L', R', and G' since,

$$\alpha c = \frac{\omega\cdot G'\cdot L'}{2\cdot\beta} \qquad \alpha d = \frac{\omega\cdot R'\cdot C'}{2\cdot\beta}$$

and previously derived, $\alpha^2 - \beta^2 = R'\cdot G' - \omega^2\cdot C'\cdot L'$

Solving for L', R', and G' yields:

$$L' = \frac{\left(\beta^2 - \alpha^2\right) + \sqrt{\left(\beta^2 - \alpha^2\right)^2 + 16\cdot\beta^2\cdot\alpha c\cdot\alpha d}}{2\cdot\omega\cdot C'}$$

and:

$$R' = \frac{2\cdot\beta\cdot\alpha c}{\omega\cdot C'} \qquad G' = \frac{2\cdot\beta\cdot\alpha d}{\omega\cdot L'}$$

Low Frequency Case:

At low frequencies, we can usually assume that the dielectric loss is negligible.

Therefore $\alpha d=0$, $G'=0$, and $\alpha=\alpha c$.

This results in two equations: $L'=\dfrac{\beta^2-\alpha^2}{\omega\cdot C'}$ $\qquad R'=\dfrac{2\cdot\beta\cdot\alpha}{\omega\cdot C'}$

However at low frequencies, the attenuation no longer varies as the square root of the frequency since the skin depth δ approaches the radius or thickness of the smallest conductor. Also the characteristic impedance of the line can change dramatically with frequency, so that α may no longer be measured into fixed and matched source and load impedances such as 50 ohms. If the loss, A, in decibels/U.L. is measured into a matched (at high frequencies) source and load impedance such as 50 or 75 ohms real, then the attenuation into matched source and load impedances, α, must be found first by iteration using the formula for the characteristic impedance of the line along with the formula for the loss into given source and load impedances.

Similarly β no longer varies linearly with frequency.....

From Gardiol, p. 200:

$$\frac{P_L}{P_M}=\frac{4\cdot R_G\cdot R_L\cdot\left(\left|Y_c\right|\right)^2}{\left[\left|\left(Z_G\cdot Z_L\cdot Y_c^{\,2}+1\right)\cdot\sinh(\gamma\cdot L)+\left(Z_G+Z_L\right)\cdot Y_c\cdot\cosh(\gamma\cdot L)\right|\right]^2}$$

$$Y_c=\sqrt{\frac{G'+\omega\cdot C'\cdot j}{R'+\omega\cdot L'\cdot j}} \qquad \gamma=\alpha+\beta\cdot j \qquad A=10\cdot\log\left(\frac{P_L}{P_M}\right)$$

Start the iteration with: $\alpha=\dfrac{A}{\left(\dfrac{20}{\ln(10)}\right)}$

M := READPRN(LDF5_50A)

$f := M^{<0>}$

$A := M^{<1>}$

vp := .89

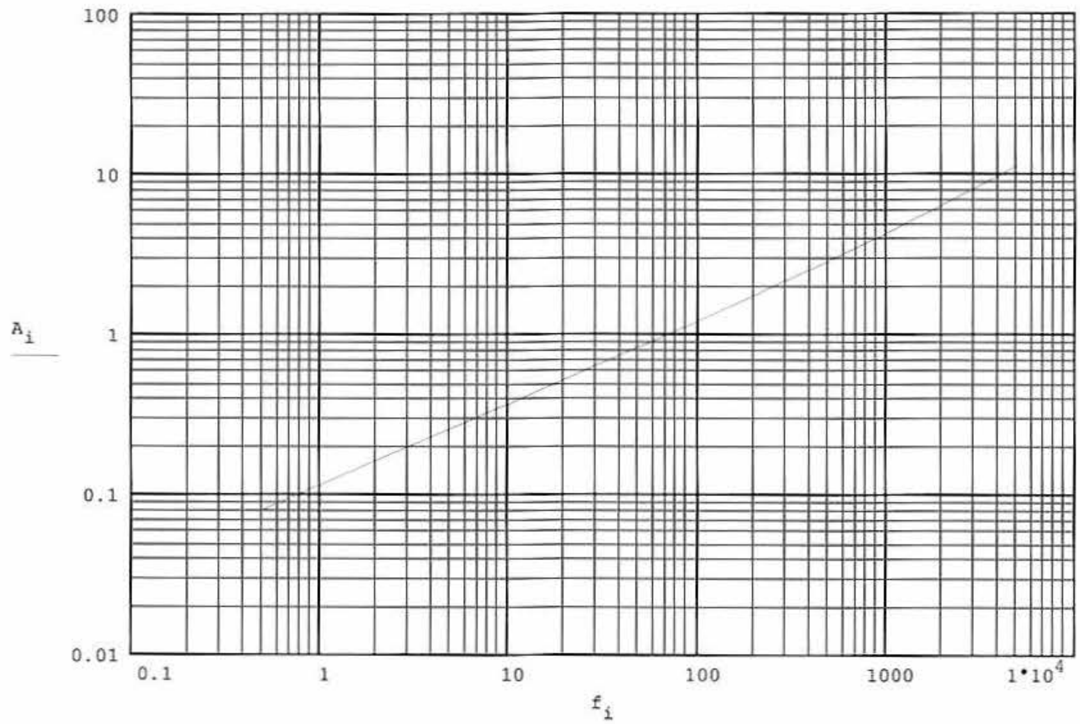
Andrew LDF5-50A.MCD
manufacturer's data

M =

f	A
0.5	0.0804
1	0.115
1.5	0.141
2	0.164
10	0.367
20	0.525
30	0.646
50	0.843
88	1.13
100	1.21
108	1.26
150	1.5
174	1.63
200	1.76
300	2.19
400	2.56
450	2.74
500	2.9
512	2.94
600	3.21
700	3.5
800	3.78
824	3.85
894	4.03
960	4.2
$1 \cdot 10^3$	4.3
$1.25 \cdot 10^3$	4.9
$1.5 \cdot 10^3$	5.45
$1.7 \cdot 10^3$	5.87
$2 \cdot 10^3$	6.46
$2.3 \cdot 10^3$	7.05
$3 \cdot 10^3$	8.31
$4 \cdot 10^3$	9.94
$5 \cdot 10^3$	11.5
$5 \cdot 10^3$	11.5

$N := 33$

$i := 0 .. N$



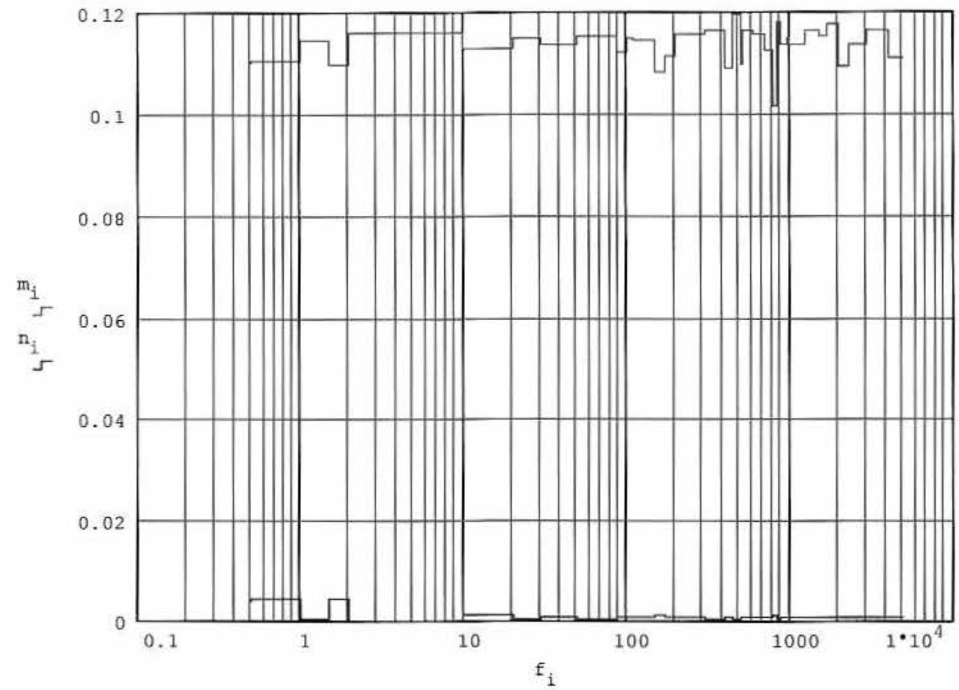
$i := 0 .. N - 1$

$$m_i := \frac{A_i \cdot f_{i+1} - A_{i+1} \cdot f_i}{f_{i+1} \cdot \sqrt{f_i} - f_i \cdot \sqrt{f_{i+1}}} \qquad n_i := \frac{A_{i+1} \cdot \sqrt{f_i} - A_i \cdot \sqrt{f_{i+1}}}{f_{i+1} \cdot \sqrt{f_i} - f_i \cdot \sqrt{f_{i+1}}}$$

$m_N := m_{N-1}$ $\qquad$ $n_N := n_{N-1}$

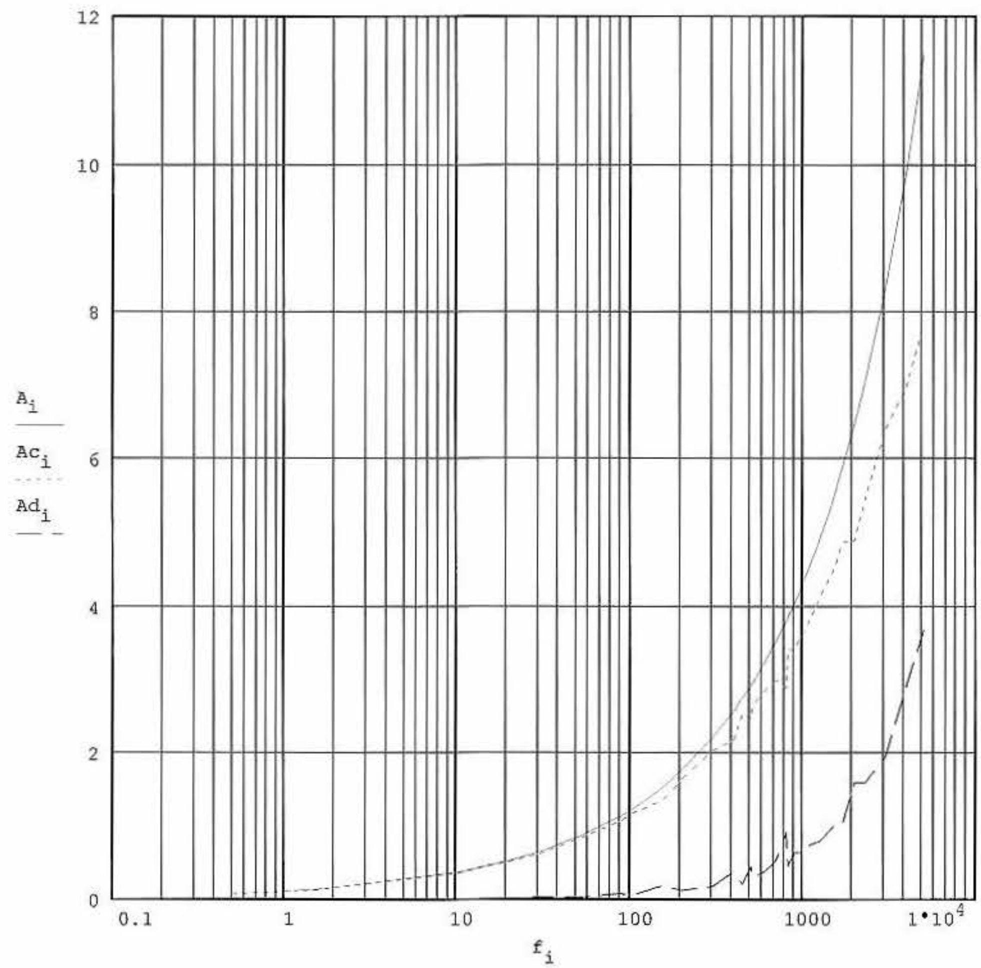
$i := 0 .. N$

f_i	m_i	n_i
0.5	0.1106	0.0044
1	0.1144	$5.6072\cdot10^{-4}$
1.5	0.1097	0.0044
2	0.1159	$5.153\cdot10^{-5}$
10	0.1128	0.001
20	0.1149	$5.4657\cdot10^{-4}$
30	0.1136	$8.0013\cdot10^{-4}$
50	0.1154	$5.3694\cdot10^{-4}$
88	0.1123	$8.7471\cdot10^{-4}$
100	0.1148	$6.2083\cdot10^{-4}$
108	0.1143	$6.6352\cdot10^{-4}$
150	0.1083	0.0012
174	0.1114	$9.2597\cdot10^{-4}$
200	0.1156	$6.2577\cdot10^{-4}$
300	0.1164	$5.8231\cdot10^{-4}$
400	0.1088	$9.6013\cdot10^{-4}$
450	0.1194	$4.5936\cdot10^{-4}$
500	0.1097	$8.9574\cdot10^{-4}$
512	0.1164	$5.9804\cdot10^{-4}$
600	0.1156	$6.3174\cdot10^{-4}$
700	0.1127	$7.4209\cdot10^{-4}$
800	0.1015	0.0011
824	0.1182	$5.5445\cdot10^{-4}$
894	0.1135	$7.1128\cdot10^{-4}$
960	0.115	$6.6288\cdot10^{-4}$
$1\cdot10^{3}$	0.1138	$7.0059\cdot10^{-4}$
$1.25\cdot10^{3}$	0.1163	$6.2986\cdot10^{-4}$
$1.5\cdot10^{3}$	0.1152	$6.5968\cdot10^{-4}$
$1.7\cdot10^{3}$	0.1178	$5.9639\cdot10^{-4}$
$2\cdot10^{3}$	0.1092	$7.886\cdot10^{-4}$
$2.3\cdot10^{3}$	0.1138	$6.9218\cdot10^{-4}$
$3\cdot10^{3}$	0.1165	$6.4273\cdot10^{-4}$
$4\cdot10^{3}$	0.1108	$7.3265\cdot10^{-4}$
$5\cdot10^{3}$	0.1108	$7.3265\cdot10^{-4}$



$$Ac_i := m_i \cdot \sqrt{f_i} \qquad Ad_i := n_i \cdot f_i$$

f_i	Ac_i	Ad_i	A_i
0.5	0.0782	0.0022	0.0804
1	0.1144	$5.6072 \cdot 10^{-4}$	0.115
1.5	0.1344	0.0066	0.141
2	0.1639	$1.0306 \cdot 10^{-4}$	0.164
10	0.3568	0.0102	0.367
20	0.5141	0.0109	0.525
30	0.622	0.024	0.646
50	0.8162	0.0268	0.843
88	1.053	0.077	1.13
100	1.1479	0.0621	1.21
108	1.1883	0.0717	1.26
150	1.3258	0.1742	1.5
174	1.4689	0.1611	1.63
200	1.6348	0.1252	1.76
300	2.0153	0.1747	2.19
400	2.1759	0.3841	2.56
450	2.5333	0.2067	2.74
500	2.4521	0.4479	2.9
512	2.6338	0.3062	2.94
600	2.831	0.379	3.21
700	2.9805	0.5195	3.5
800	2.8721	0.9079	3.78
824	3.3931	0.4569	3.85
894	3.3941	0.6359	4.03
960	3.5636	0.6364	4.2
$1 \cdot 10^3$	3.5994	0.7006	4.3
$1.25 \cdot 10^3$	4.1127	0.7873	4.9
$1.5 \cdot 10^3$	4.4605	0.9895	5.45
$1.7 \cdot 10^3$	4.8561	1.0139	5.87
$2 \cdot 10^3$	4.8828	1.5772	6.46
$2.3 \cdot 10^3$	5.458	1.592	7.05
$3 \cdot 10^3$	6.3818	1.9282	8.31
$4 \cdot 10^3$	7.0094	2.9306	9.94
$5 \cdot 10^3$	7.8367	3.6633	11.5



Let:

$$\alpha_i := \frac{A_i}{\left(\frac{20}{\ln(10)}\right)\cdot 100} \qquad \alpha c_i := \frac{Ac_i}{\left(\frac{20}{\ln(10)}\right)\cdot 100} \qquad \alpha d_i := \frac{Ad_i}{\left(\frac{20}{\ln(10)}\right)\cdot 100}$$

$$c := 2.9979\cdot 10^8 \qquad f_{26} = 1.25\cdot 10^3 \qquad \alpha_{26} = 0.0056 \qquad \frac{20}{\ln(10)} = 8.6859$$

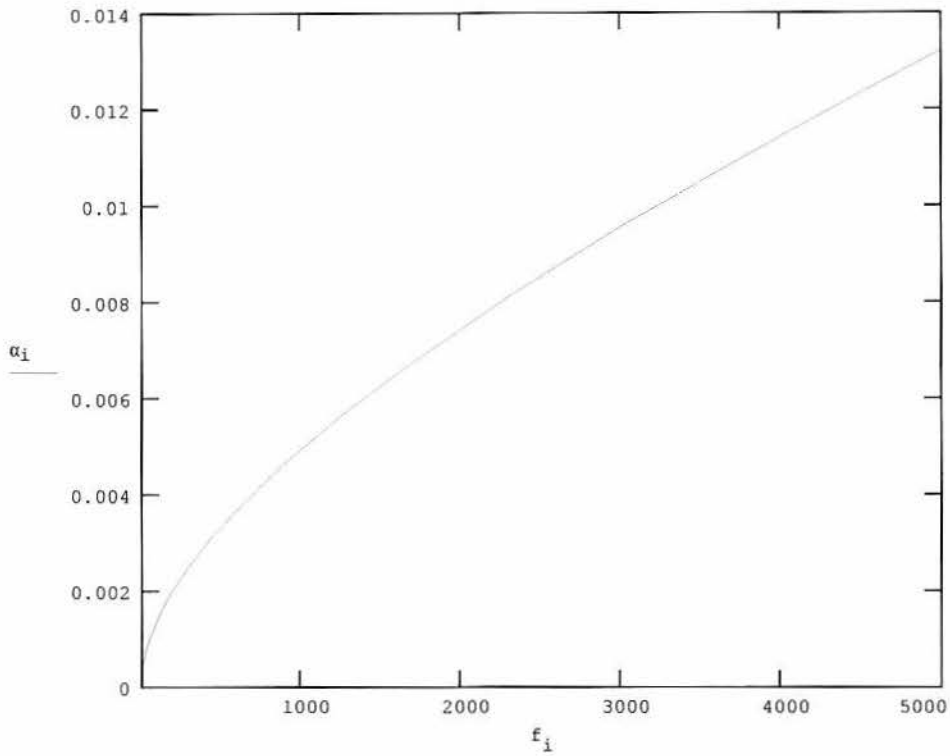
$$vp := .89 \qquad \omega_i := 2\cdot\pi\cdot f_i\cdot 10^6 \qquad \beta_i := \frac{\omega_i}{vp\cdot c} \qquad C := 75.0\cdot 10^{-12}$$

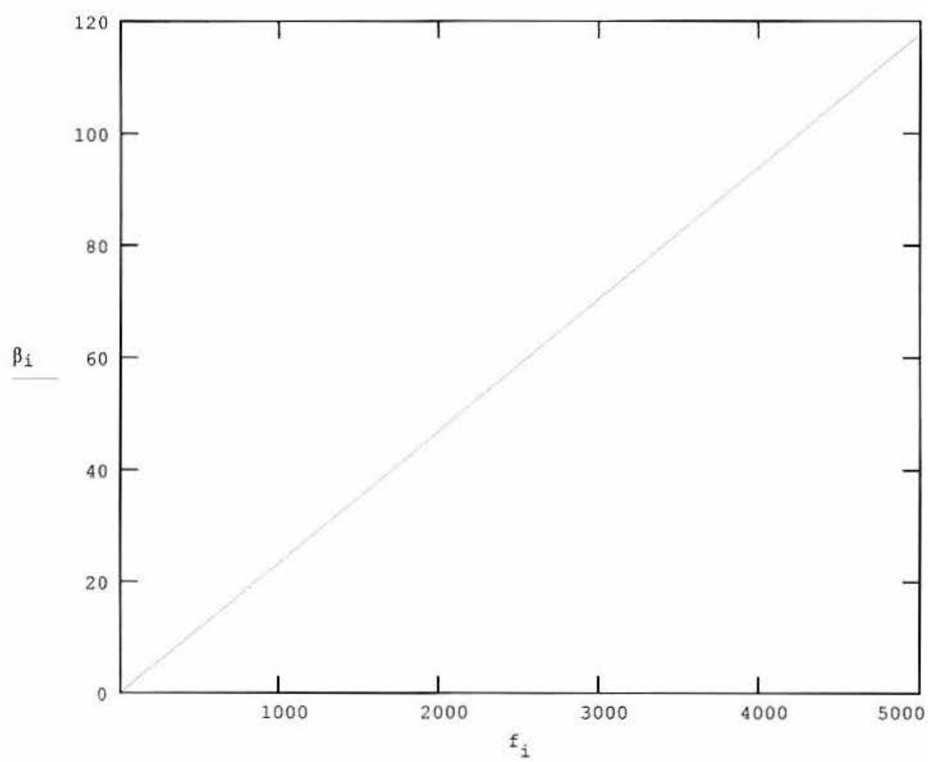
$$\omega_{26} = 7.854\cdot 10^9 \qquad \beta_{26} = 29.4363 \qquad A_{26} = 4.9$$

$$L_i := \frac{\left[\left(\beta_i\right)^2 - \left(\alpha_i\right)^2\right] + \sqrt{\left[\left(\beta_i\right)^2 - \left(\alpha_i\right)^2\right]^2 + 16\cdot\left(\beta_i\right)^2\cdot \alpha c_i\cdot \alpha d_i}}{2\cdot\left(\omega_i\right)^2\cdot C}$$

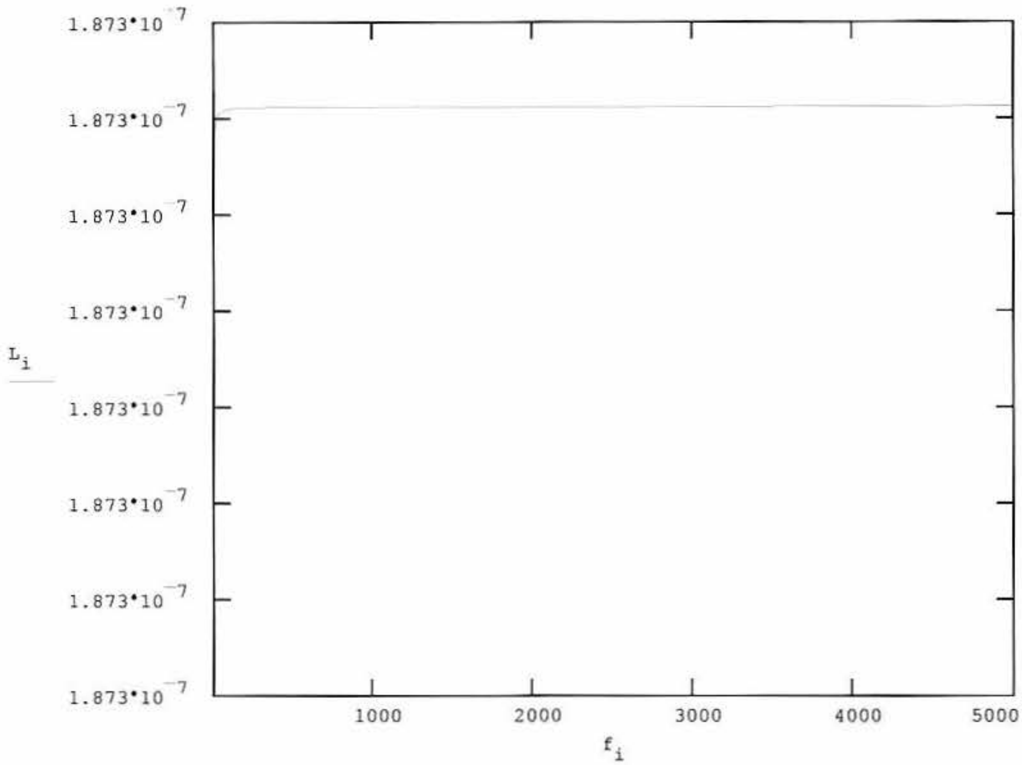
$$R_i := \frac{2\cdot\beta_i\cdot\alpha c_i}{\omega_i\cdot C} \qquad G_i := \frac{2\cdot\beta_i\cdot\alpha d_i}{\omega_i\cdot L_i}$$

f_i	α_i	β_i
0.5	$9.2564 \cdot 10^{-5}$	0.0118
1	$1.324 \cdot 10^{-4}$	0.0235
1.5	$1.6233 \cdot 10^{-4}$	0.0353
2	$1.8881 \cdot 10^{-4}$	0.0471
10	$4.2252 \cdot 10^{-4}$	0.2355
20	$6.0443 \cdot 10^{-4}$	0.471
30	$7.4373 \cdot 10^{-4}$	0.7065
50	$9.7054 \cdot 10^{-4}$	1.1775
88	0.0013	2.0723
100	0.0014	2.3549
108	0.0015	2.5433
150	0.0017	3.5324
174	0.0019	4.0975
200	0.002	4.7098
300	0.0025	7.0647
400	0.0029	9.4196
450	0.0032	10.5971
500	0.0033	11.7745
512	0.0034	12.0571
600	0.0037	14.1294
700	0.004	16.4843
800	0.0044	18.8392
824	0.0044	19.4044
894	0.0046	21.0528
960	0.0048	22.6071
$1 \cdot 10^{3}$	0.005	23.549
$1.25 \cdot 10^{3}$	0.0056	29.4363
$1.5 \cdot 10^{3}$	0.0063	35.3235
$1.7 \cdot 10^{3}$	0.0068	40.0333
$2 \cdot 10^{3}$	0.0074	47.098
$2.3 \cdot 10^{3}$	0.0081	54.1627
$3 \cdot 10^{3}$	0.0096	70.647
$4 \cdot 10^{3}$	0.0114	94.1961
$5 \cdot 10^{3}$	0.0132	117.7451


0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
α_i
1000
2000
3000
4000
5000
f_i


120
100
80
60
40
20
0
β_i
1000
2000
3000
4000
5000
f_i

f_i	L_i	R_i	G_i
0.5	$1.8728\cdot10^{-7}$	0.009	$1.0204\cdot10^{-7}$
1	$1.8729\cdot10^{-7}$	0.0132	$2.5837\cdot10^{-8}$
1.5	$1.8729\cdot10^{-7}$	0.0155	$3.0624\cdot10^{-7}$
2	$1.8729\cdot10^{-7}$	0.0189	$4.7488\cdot10^{-9}$
10	$1.8729\cdot10^{-7}$	0.0411	$4.7066\cdot10^{-7}$
20	$1.8729\cdot10^{-7}$	0.0592	$5.0369\cdot10^{-7}$
30	$1.8729\cdot10^{-7}$	0.0716	$1.106\cdot10^{-6}$
50	$1.8729\cdot10^{-7}$	0.0939	$1.237\cdot10^{-6}$
88	$1.8729\cdot10^{-7}$	0.1212	$3.5468\cdot10^{-6}$
100	$1.8729\cdot10^{-7}$	0.1321	$2.8606\cdot10^{-6}$
108	$1.8729\cdot10^{-7}$	0.1367	$3.3019\cdot10^{-6}$
150	$1.8729\cdot10^{-7}$	0.1526	$8.0253\cdot10^{-6}$
174	$1.8729\cdot10^{-7}$	0.169	$7.4239\cdot10^{-6}$
200	$1.8729\cdot10^{-7}$	0.1881	$5.7667\cdot10^{-6}$
300	$1.8729\cdot10^{-7}$	0.2319	$8.0493\cdot10^{-6}$
400	$1.8729\cdot10^{-7}$	0.2504	$1.7696\cdot10^{-5}$
450	$1.8729\cdot10^{-7}$	0.2915	$9.5247\cdot10^{-6}$
500	$1.8729\cdot10^{-7}$	0.2822	$2.0637\cdot10^{-5}$
512	$1.8729\cdot10^{-7}$	0.3031	$1.4109\cdot10^{-5}$
600	$1.8729\cdot10^{-7}$	0.3257	$1.7465\cdot10^{-5}$
700	$1.8729\cdot10^{-7}$	0.343	$2.3935\cdot10^{-5}$
800	$1.8729\cdot10^{-7}$	0.3305	$4.1833\cdot10^{-5}$
824	$1.8729\cdot10^{-7}$	0.3904	$2.1051\cdot10^{-5}$
894	$1.8729\cdot10^{-7}$	0.3905	$2.93\cdot10^{-5}$
960	$1.8729\cdot10^{-7}$	0.4101	$2.9322\cdot10^{-5}$
$1\cdot10^{3}$	$1.8729\cdot10^{-7}$	0.4142	$3.2281\cdot10^{-5}$
$1.25\cdot10^{3}$	$1.8729\cdot10^{-7}$	0.4732	$3.6278\cdot10^{-5}$
$1.5\cdot10^{3}$	$1.8729\cdot10^{-7}$	0.5132	$4.5594\cdot10^{-5}$
$1.7\cdot10^{3}$	$1.8729\cdot10^{-7}$	0.5588	$4.6716\cdot10^{-5}$
$2\cdot10^{3}$	$1.8729\cdot10^{-7}$	0.5618	$7.2673\cdot10^{-5}$
$2.3\cdot10^{3}$	$1.8729\cdot10^{-7}$	0.628	$7.3355\cdot10^{-5}$
$3\cdot10^{3}$	$1.8729\cdot10^{-7}$	0.7343	$8.8845\cdot10^{-5}$
$4\cdot10^{3}$	$1.8729\cdot10^{-7}$	0.8065	$1.3503\cdot10^{-4}$
$5\cdot10^{3}$	$1.8729\cdot10^{-7}$	0.9017	$1.6879\cdot10^{-4}$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1.873*10^-7
1.873*10^-7
1.873*10^-7
1.873*10^-7
1.873*10^-7
1.873*10^-7
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L_i
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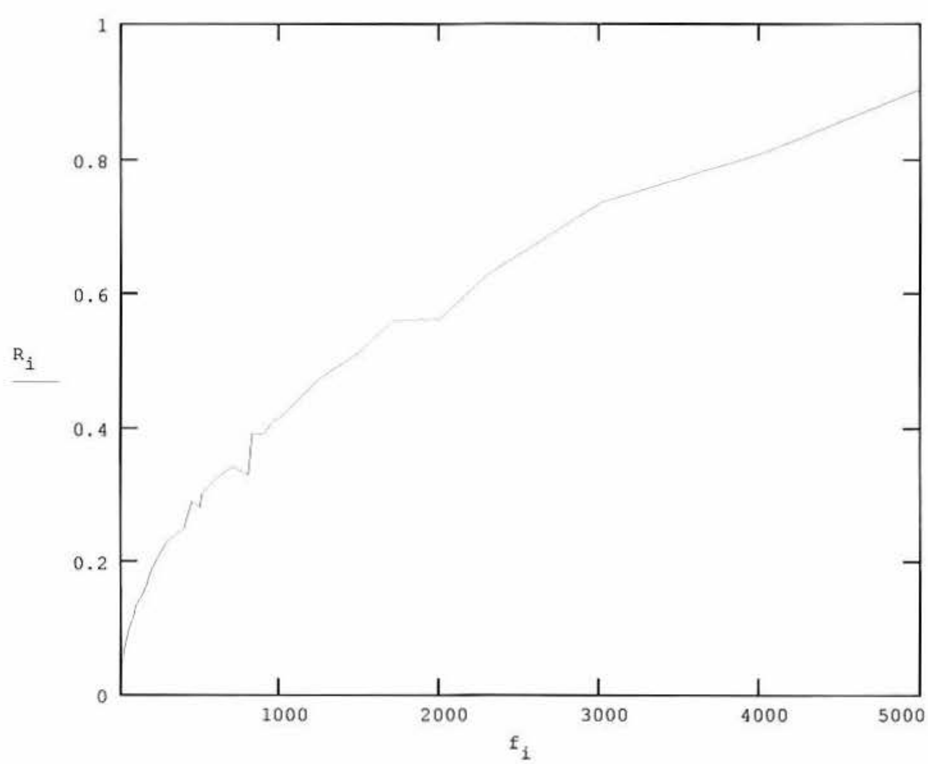
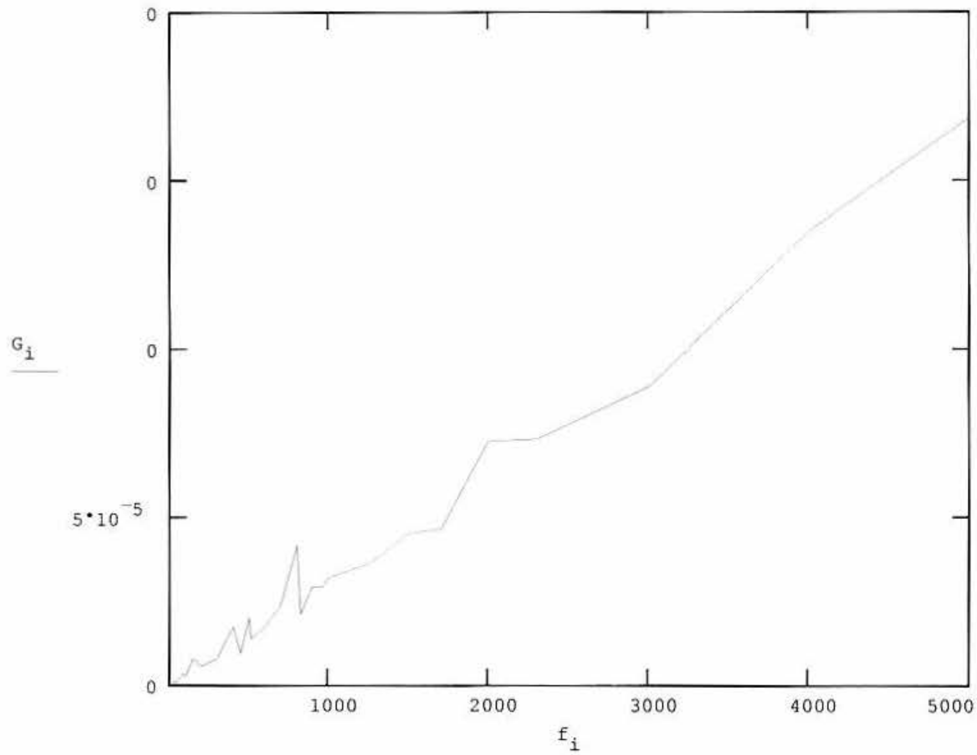
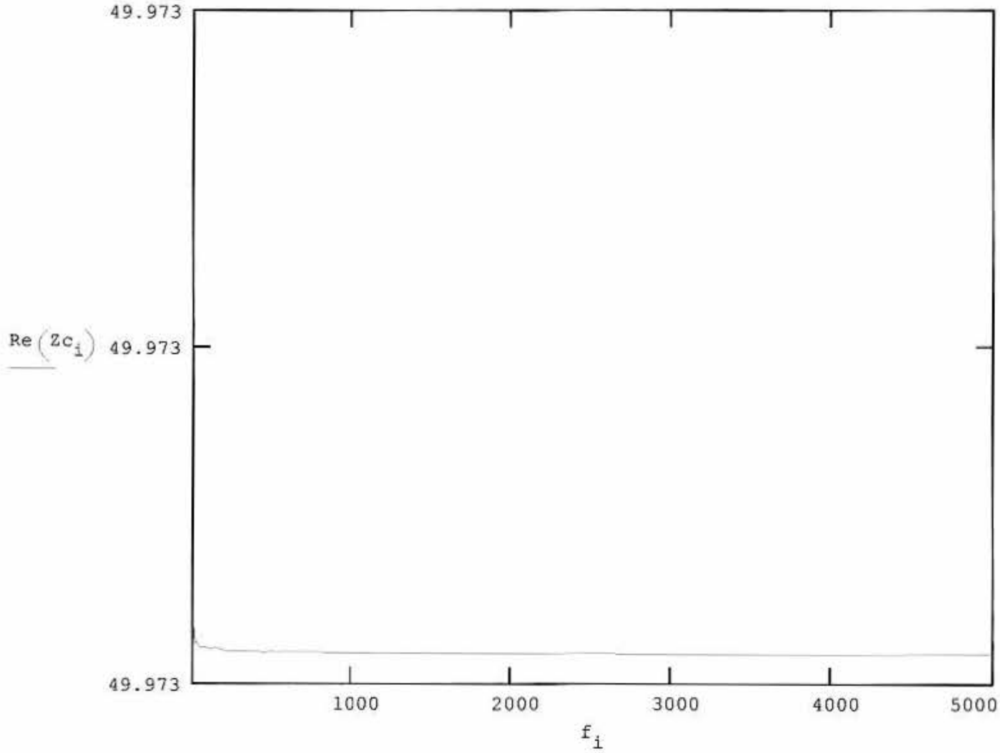
2000
3000
4000
5000
f_i


1
0.8
0.6
0.4
0.2
0
R_i
1000
2000
3000
4000
5000
f_i

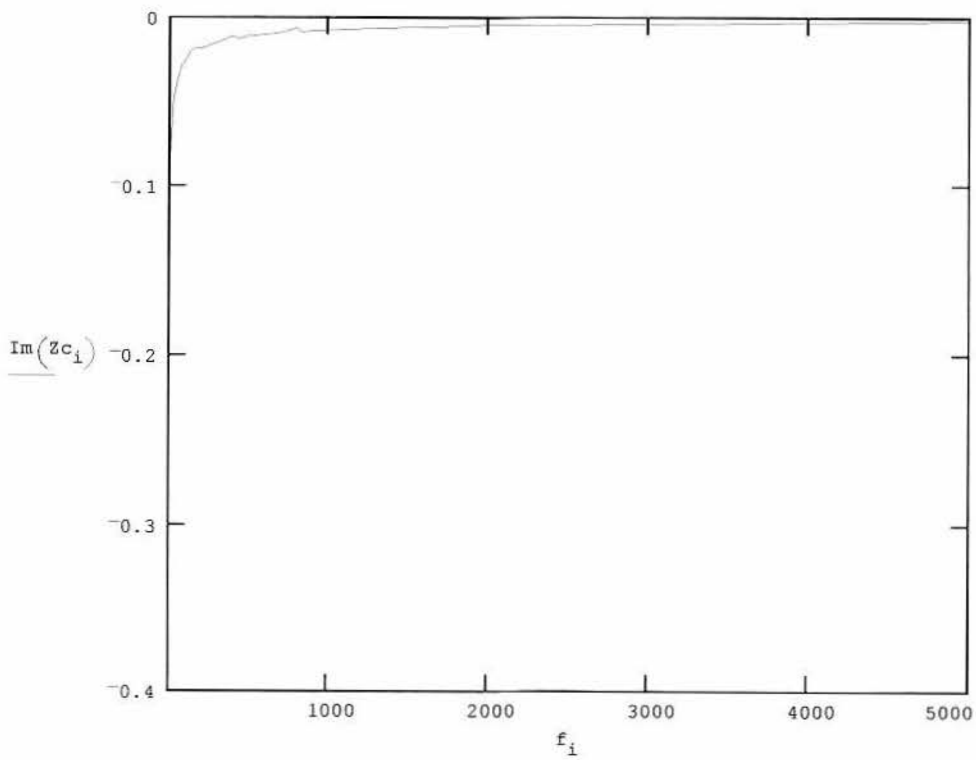


$$Zc_i = \sqrt{\frac{R_i + \omega_i \cdot L_i \cdot j}{G_i + \omega_i \cdot C \cdot j}}$$

f_i	Zc_i
0.5	49.9727 − 0.3712j
1	49.9726 − 0.2782j
1.5	49.9726 − 0.208j
2	49.9726 − 0.2001j
10	49.9726 − 0.0847j
20	49.9726 − 0.0615j
30	49.9726 − 0.0487j
50	49.9726 − 0.0386j
88	49.9726 − 0.0271j
100	49.9726 − 0.0265j
108	49.9726 − 0.0253j
150	49.9726 − 0.0188j
174	49.9726 − 0.0184j
200	49.9726 − 0.0184j
300	49.9726 − 0.015j
400	49.9726 − 0.0109j
450	49.9726 − 0.0126j
500	49.9726 − 0.0098j
512	49.9726 − 0.0111j
600	49.9726 − 0.01j
700	49.9726 − 0.0086j
800	49.9726 − 0.006j
824	49.9726 − 0.0087j
894	49.9726 − 0.0075j
960	49.9726 − 0.0074j
$1 \cdot 10^3$	49.9726 − 0.0071j
$1.25 \cdot 10^3$	49.9726 − 0.0065j
$1.5 \cdot 10^3$	49.9726 − 0.0057j
$1.7 \cdot 10^3$	49.9726 − 0.0055j
$2 \cdot 10^3$	49.9726 − 0.004j
$2.3 \cdot 10^3$	49.9726 − 0.0041j
$3 \cdot 10^3$	49.9726 − 0.0036j
$4 \cdot 10^3$	49.9726 − 0.0025j
$5 \cdot 10^3$	49.9726 − 0.002j



49.973
Re(Zc_i) 49.973
49.973
1000
2000
3000
4000
5000
f_i



0
-0.1
Im(Zc_i) -0.2
-0.3
-0.4
1000
2000
3000
4000
5000
f_i

Type LDF5-50A

7/8" Foam Dielectric

50-ohm

Superior to Braided Cable

Solid copper corrugated outer conductor results in low loss, high power handling and continuous RFI/EMI shielding to minimize interference and maximize system security. Cable can be formed to a 10 in (250 mm) radius.

Weatherproof

Annular corrugations prevent water migration. Connector O-rings seal out moisture. Closed cell foam prevents water penetration.

Quick and Easy Connector Attachment

Patented, self-flaring design.

Low Loss Foam

Pressurization not required.

Proven performance in applications such as:

- Industry standard in land mobile radio.
- Cellular radio.
- Phase stabilized versions for phased array radars.
- VLF and HF communications systems; AM and FM radio broadcast.
- Mil-spec versions available.

Low VSWR Cable

Type LDF5P-50A is a low-VSWR version of LDF5-50A. Low VSWR specifications are tabulated on the right. Achievable VSWR is a function of maximum operating frequency, connector interfaces and cable length. The figures are guaranteed for factory assemblies and are typical for field cut lengths. If two different interfaces are used, the higher VSWR value is the guarantee.

Standard operating frequency bands include those commonly used for terrestrial microwave and satellite communication earth station applications:

Terrestrial Microwave Low VSWR specifications for frequency bands (Specify bands):

1.427-1.535 GHz	1.15 (23.1)	2.11-2.2 GHz	1.12 (24.9)
1.7-1.9 GHz	1.15 (23.1)	1.7-2.11 GHz	1.15 (23.1)
1.85-1.99 GHz	1.12 (24.9)	1.9-2.3 GHz	1.15 (23.1)
1.99-2.11 GHz	1.15 (23.1)	2.3-2.7 GHz	1.20 (20.8)

Low VSWR cable for cellular radio is listed in the "Characteristics" table.

Earth Station 3.625-4.2 GHz

Characteristics

Nominal Size	7/8"
Impedance, ohms	50***

Cable Type Numbers

Standard Cable, Standard Jacket	LDF5-50A*
Standard Cable, Fire-Retardant, Non-Halogenated Jacket	LDF5RN-50A
Specially Tested and Selected Cable	
Low-VSWR Cable (Specify Operating Band, see table below)	LDF5P-50A
Cellular Radio	
824-894 MHz, 1.20 max. VSWR	42150B-48
880-960 MHz, 1.20 max. VSWR	42150B-54
Qualified to MIL-C-28830/4	202071-2

Electrical Characteristics

Maximum Frequency, GHz	5.0
Velocity, percent	89
Peak Power Rating, kW	44
DC Resistance, ohms/1000 ft (1000 m)	
Inner	0.35 (1.15)
Outer	0.36 (1.18)
DC Breakdown, volts	6000
Jacket Spark, volts RMS	8000
Capacitance, pF/ft (m)	22.8 (75.0)
Inductance, μH/ft (m)	0.057 (0.187)

Mechanical Characteristics

Outer Conductor	Copper
Inner Conductor	Copper
Diameter over Jacket, in (mm)	1.09 (28)
Diameter over Copper Outer Conductor, in (mm)	0.98 (24.9)
Minimum Bending Radius, in (mm)	10 (250)
Number of Bends, minimum (typical)	15 (50)
Bending Moment, ft-lb (N·m)	12 (16.3)
Cable Weight, lb/ft (kg/m)	0.33 (0.49)
Tensile Strength, lb (kg)	325 (147)
Flat Plate Crush Strength, lb/in (kg/mm)	80 (1.4)

*For broadcast applications, specify TV channel or frequency.

***A 75-ohm 7/8" diameter cable is available. Contact Andrew for further information.

Low VSWR Specifications, Type LDF5P-50A

Up to Freq. GHz	Using Connector Type No.	Assembly VSWR, Maximum (R.L., dB) to 25 ft (8 m)	25 - 100 ft (8 - 30 m)	100 - 200 ft (30 - 60 m)
1.7†	L45W (N Plug)	1.10 (26.4)	1.20 (20.8)	1.30 (17.7)
	L45N (N Jack)	1.12 (24.9)	1.22 (20.1)	1.33 (17.0)
	L45F or L45R	1.10 (26.4)	1.20 (20.8)	1.30 (17.7)
2.7†	L45W (N Plug)	1.10 (26.4)	1.20 (20.8)	1.30 (17.7)
	L45N (N Jack)	1.15 (23.1)	1.25 (19.1)	1.35 (16.6)
	L45F or L45R	1.15 (23.1)	1.25 (19.1)	1.35 (16.6)
4.2	L45W (N Plug)	1.10 (26.4)	1.20 (20.8)	1.35 (16.6)
5.0	L45W (N Plug)	1.15 (23.)	1.20 (20.8)	1.35 (16.6)

†See "Terrestrial Microwave" on the left for data on specific narrow bands.

Attenuation and Average Power

Frequency MHz	Attenuation dB/100 ft	Attenuation dB/100m	Average Power kW	Frequency MHz	Attenuation dB/100 ft	Attenuation dB/100 m	Average Power kW
0.5	0.0245	0.0804	44.0	500	0.885	2.90	2.25
1	0.0350	0.115	44.0	512	0.896	2.94	2.22
1.5	0.0431	0.141	44.0	600	0.979	3.21	2.03
2	0.0500	0.164	40.0	700	1.07	3.50	1.86
10	0.112	0.367	17.7	800	1.15	3.78	1.73
20	0.160	0.525	12.4	824	1.17	3.85	1.70
30	0.197	0.646	10.1	894	1.23	4.03	1.62
50	0.257	0.843	7.74	960	1.28	4.20	1.56
88	0.345	1.13	5.75	1000	1.31	4.30	1.52
100	0.369	1.21	5.38	1250	1.49	4.90	1.33
108	0.384	1.26	5.17	1500	1.66	5.45	1.20
150	0.458	1.50	4.34	1700	1.79	5.87	1.11
174	0.496	1.63	4.01	2000	1.97	6.46	1.01
200	0.535	1.76	3.72	2300	2.15	7.05	0.926
300	0.668	2.19	2.98	3000	2.53	8.31	0.785
400	0.781	2.56	2.55	4000	3.03	9.94	0.656
450	0.834	2.74	2.39	5000	3.50	11.5	0.568

Standard Conditions:
For Attenuation. VSWR 1.0, ambient temperature 24°C (75°F).

For Average Power. VSWR 1.0, ambient temperature 40°C (104°F), inner conductor temperature 100°C (212°F).

Connectors

Interface - See photos on pages 332 and 333	Type No.	Length in (mm)	Body Dia. in (mm)	Flange Dia. in (mm)	Weight lb (kg)
"F" (male) connects with "F"-Series antennas	L45F	1.76 (44.7)	1.40 (35.6)	2.25 (57.2)	1.5 (0.7)
"F" Flange (female) for connection to jumper cable	48041	1.76 (44.7)	1.40 (35.6)	2.25 (57.2)	1.5 (0.7)
7/8 EIA Flange, no gas barrier at interface, includes inner connector	L45R	3.32 (84.3)	1.35 (34.3)	2.25 (57.2)	1.5 (0.7)
7/8 EIA Flange,right angle, no gas barrier at interface, includes inner connector	124800-1	3.94 (100.0)	1.34 (34.0)	2.25 (57.2)	1.5 (0.7)
N Plug (male), mates with UG-23	L45W	2.83 (71.9)	1.37 (34.8)	–	1.5 (0.7)
N Plug (male), low VSWR, mates with UG-23	L45EW*	2.83 (71.9)	1.37 (34.8)	–	1.5 (0.7)
N Jack (female), mates with UG-21	L45N	2.80 (71.1)	1.35 (34.3)	–	1.5 (0.7)
UHF Plug (male), mates with SO-239A	L45P	2.70 (68.5)	1.35 (34.3)	–	1.5 (0.7)
UHF Jack (female), mates with PL-259A	L45U	2.68 (68.1)	1.35 (34.3)	–	1.5 (0.7)
LC Plug (male), mates with UG-352	L45M	3.69 (93.7)	1.34 (34.0)	–	1.5 (0.7)
LC Jack (female), mates with UG-154	L45L	3.42 (86.8)	1.35 (34.3)	–	1.5 (0.7)
HN Plug (male), mates with UG-60	L45J	2.95 (74.9)	1.34 (34.0)	–	1.5 (0.7)
7/16 DIN male	L45DM	2.63 (66.7)	1.38 (35.1)	–	1.5 (0.7)
7/16 DIN female	L45DF	2.72 (69.1)	1.36 (34.5)	–	1.5 (0.7)
End Terminal, for strap connection to center conductor	L45T	4.88 (123.8)	1.35 (34.3)	–	1.5 (0.7)
Splice	L45Z	3.34 (84.8)	1.47 (37.3)	–	1.5 (0.7)
Connector Pin-Paks, five replacement pins					
For L45W	43158-5	–	–	–	–
For L45N	43157-2	–	–	–	–

For RF connector adaptors, see page 334.

*Connector for low-VSWR applications. Includes gold-plated inner connector and nickel-plated body.

Accessories - See page 301

To Order

- A sample order is shown on page 273.
- Specify cable Type Number and length in feet or metres. See "Characteristics" table.
- For low-VSWR cable, specify the operating frequency band (see "Low-VSWR Cables" for standard frequency bands and VSWR/Return Loss specifications).
- Specify connector Type Numbers and "attached" or "unattached". When attached connectors on an assembly are different, specify which is "first off" the reel.

Further Information

For general information on HELIAX coaxial cables see pages 268-273.